100 BeV/c RF SEPARATED BEAM--1968 MODIFICATION

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Most of what was presented in the 100 BeV/c rf beam design of Ref. 1 is still relevant, and I would like to dwell only on those features which should be revised because of technological advances which have come about in the three years since the above report was written.[1]

Superconducting Deflectors

The prospects for superconductivity deflectors now appears much better than at the time of the above report. The Stanford group has successfully constructed superconducting linac cavities, and the BNL group have also constructed superconducting S-band structures. None of the structures have operated in the deflecting mode, but there appears to be no reason to believe that they will be more difficult to construct than the linac structure. Most of the present work has been done at S-band, and the majority of these structures have been fabricated of copper with the interior surfaces being plated with lead to give the desired conducting surface. This lead plating is a difficult and somewhat tricky process--although it has been done successfully--but very recent developments indicate that cavities fabricated of solid niobium, are very promising. An active developmental program investigating these new materials and their application to superconducting deflectors is being pursued at BNL. Plans are now underway at BNL for the development of S-band superconducting deflectors to be used in a 20 BeV/c rf separated counter beam. This beam should be constructed in the next two years and should prove a good test of superconducting deflectors.

RF Deflection

The beam described in Ref. 1 assumed that superconducting deflectors were not available and was an attempt to see how a conventional deflector could be pushed. It assumed that at 100 BeV/c a deflection of 0.05 mrad could be achieved in each deflector, this being a limit imposed by the availability of X-band power sources. With the advent of superconducting structures the limit would be sparking within the cavity which occurs at fields corresponding to about 6 MeV/c deflection per meter of deflector. We see now that with an X-band structure 3-m long, we can get a deflection of

$$\theta_0 = \frac{(3\text{m})(6\ \text{MeV/c/m})}{100\ \text{BeV/c}}$$

$$= 0.18\ \text{mrad at } 100\ \text{BeV/c}.$$

The phase acceptance of such a structure is shown in Fig. 1. Here I have assumed that the acceptance is given by the inscribed square of the deflector and that the deflector aperture is approximately $\lambda/z \sim 1.5$ cm.

Assuming a target size of 1 mm horizontally and 0.5 mm vertically, we shall be able to fill the deflector if we assume acceptance angles of ±1 mrad vertically at the target and magnify ~ 10 before we enter the first deflector. This gives us a natural beam divergence, θ_n, of ±0.1 mrad in the first deflector. A convenient figure of merit F_m is

$$F_m = \frac{\theta_0}{\theta_n} .$$

For this beam $F_m = 2$, whereas for the present BNL beam $F_m = 1$. It should be noted that I have assumed a real image is found in the deflector. This is not an efficient match into the deflector, and it may well be that more efficient matching schemes ("skew optics") could result in longer deflectors, hence greater deflection and/or higher intensities.

The larger deflection proposed here compared to Ref. 1 requires a redesign of the interdeflector sections to accept the much larger angular deflections. This is straightforward but will require more magnets.

Front End

Targeting in the beams proposed in Ref. 1 was assumed to be in the Berkeley designed target stations, and this type of target station has been dropped. Table I represents an attempt at a more conventional front end design. Here the target angle has not been specified, but it is assumed to be on the order of a few milliradians.

Choice of Frequency

With the advent of superconducting deflectors, it is possible that a frequency somewhat higher than X-band is desirable. The present design--especially if more effective use were made of the deflector acceptance, e.g. by use of "skew optics," could tolerate a higher frequency and the inherently smaller aperture associated with it. A higher frequency would have two advantages:

(i) A reduction in the real estate needed for such a beam since the interdeflector separation is inversely proportional to the frequency for a fixed momentum.

(ii) A shorter beam will reduce the losses of wanted particles through decay. This is only serious for K's in that the number that survive at 100 and 50 BeV/c respectively are 31% and 3.5%.

However, a very serious question exists as to how much higher the frequency could be pushed. The fabrication tolerances of the deflector are proportional to the wavelength. These are already stringent at S-band, and it is a detailed engineering question as to whether the required tolerances can be maintained at frequencies above X-band.

Beam Length

It is interesting to see how we might reduce the length of our 100 BeV/c beam if we place as a ground rule that we stay at 10 GHz. Let's list the possibilities:

(i) The beam of reference can probably be reduced in length by 100-200 m just be further optimization and perhaps by removal of the "re-imaging section" if more detailed computations show this will not adversely affect the purity.

(ii) The primary proton could be passed through an X-band deflector and the target placed so that this modulated beam strikes it and produces an X-band modulated secondary beam.

Advantages

The beam length would be reduced by about 25%.

Disadvantages

(i) Less than 1/2 of the proton intensity could be used for secondary particle production in the rf beam.

(ii) For the same total length of deflector the deflections of the wanted particles would be smaller since the first deflector would be used as the primary beam modulator.

Since in such a system a momentum analysis would be performed in the interdeflector sections, people have worried about isochronism in the momentum analysis plane. However, D. Berley, in a separate report, points out that the condition for a dispersion recombined image is identical with that of canceling the anisochronism inherent in a single bending magnet.

(iii) As in (ii), the proton beam could be modulated but now would be swept twice across the target or septum for each X-band cycle thus effectively doubling the frequency.

Advantages

The interdeflector drift distances could now be reduced by a factor of two as well as now having the drift distance starting from the target. Thus, the overall beam length could be reduced by a factor of about 2 to about 500-600 m.

Disadvantages

These would be similar to scheme (ii) except that now even a smaller fraction of the proton beam would impinge upon the target. This is not as serious as it might seem for K's since the decay losses would be much less and at lower momenta such a scheme would probably even result in more intense K beams. This would represent an intensity limitation for all other types of particles however.

Such a scheme appears to be a very tempting idea and should be seriously considered for the BNL superconducting rf beam.

400 BeV?

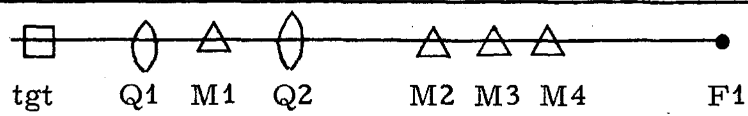
If the machine energy were raised to 400 BeV soon (1-2 years) after turn-on and one were interested in producing an rf beam at 200 or 300 BeV/c, one would be faced with the following drift distances assuming one did not use any tricks such as frequency doubling.

	200 BeV/c	300 BeV/c
10 GHz	2.75 km	6.19
20 GHz	1.37	3.10
40 GHz	0.68	1.65

REFERENCE

[1] J. Lach, 200-BeV Accelerator: Studies in Experimental Use, Lawrence Radiation Laboratory UCRL-16830, Vol. I, 1965, p. 190.

Table I. Conventional Front End Design of a 100 BeV/c Beam.



Components	
Target	0.5 mm vert., 1 mm hor.
Space	21.25 m
Quadrupole	1.25 m × 2 in. aperture, B = -8 kG at pole tip
Space	0.25 m
Bend	5.0 m × 1 in. × 2 in., B = 7.5 kG, bends 11 mrads
Space	0.25 m
Quadrupole	1.25 m × 2 in. aperture, B = 7 kG at pole tip
Space	0.25 m
Bend	5.0 m × 1 in. × 2 in., B = 7.5 kG, bends 11 mrads
Space	0.25 m
Bend	5.0 m × 1 in. × 2 in., B = 7.5 kG. bends 11 mrads
Space	0.25 m
Bend	5.0 m × 1 in. × 2 in., B = 7.5 kG, bends 11 mrads
Space	30 m

Total length: 75 m

The above possible front end for the rf beam has about the optical characteristics of the front end of the beam in Ref. 1 without the Berkeley target stations.

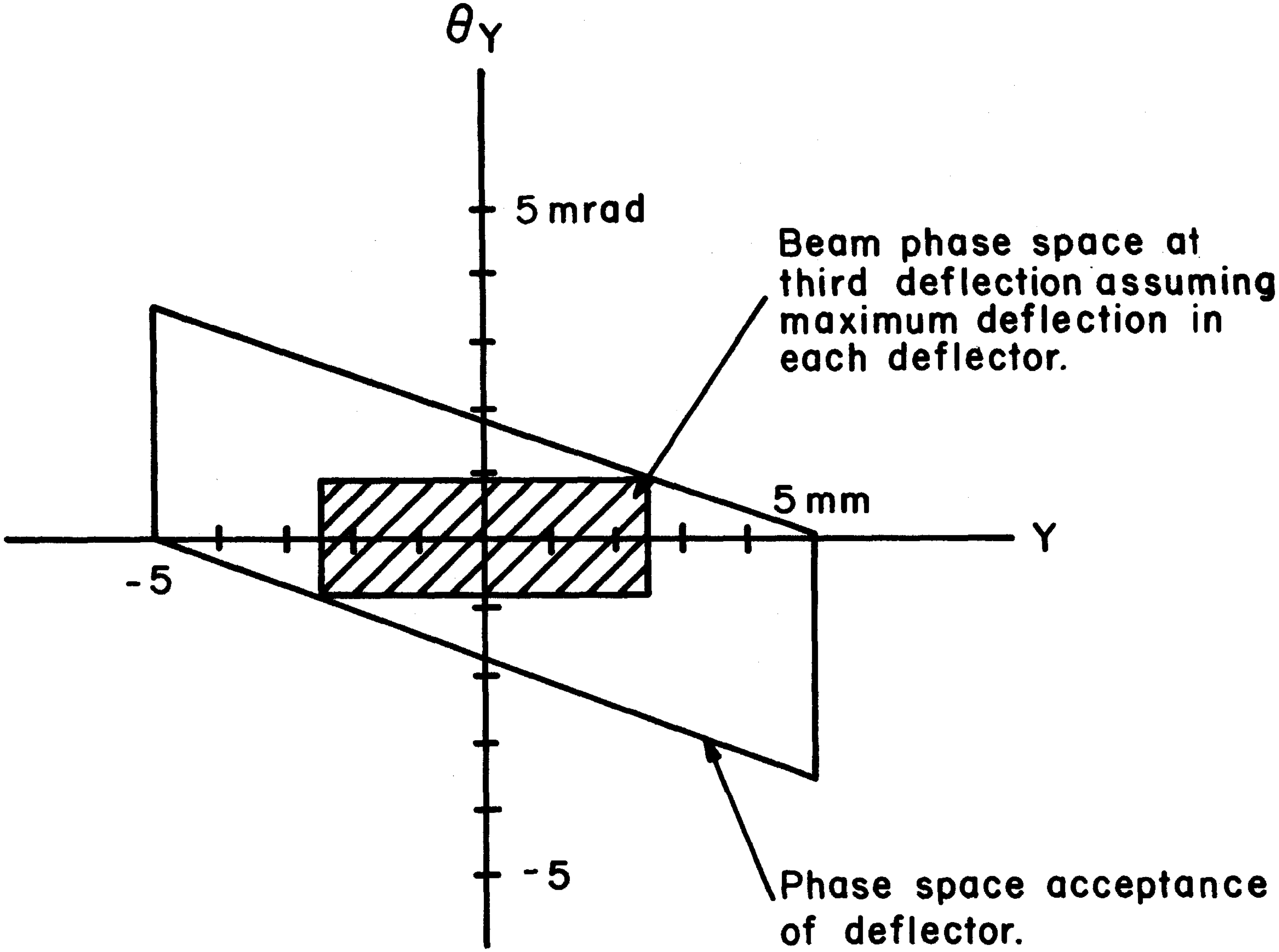


Fig. 1. Phase-space acceptance for an rf-separated beam.